M. High-Density Infrared Surface Treatment of Materials for Heavy-Duty Vehicles

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Objectives

- Use high-density infrared (HDI) technology to produce corrosion- and/or wear-resistant coatings on metal substrates.
- Use lighter or more cost-effective bulk materials with coatings applied to surfaces where improved properties are required.

Approach

- Examine approaches to surface modification that would be of interest for materials for heavy-duty vehicles.
- First examine the application and formation of adherent, wear-/corrosion-resistant coatings.
- Base the initial tests on hardmetal compositions applied onto iron-based parts that are currently used in diesel engines.

Accomplishments

- Demonstrated the ability to produce adherent hardmetal-based coatings with low trapped porosity on three different metal substrates.
- Showed improved wear resistance for coatings produced using HDI.

Future Direction

- Examine the relationships between processing parameters, microstructural development, and wear resistance.

Introduction

HDI technology is relatively new in the materials processing area and is gradually being exploited. The HDI processing facility at Oak Ridge National Laboratory (ORNL) uses a unique technology to produce extremely high power densities of up to 3.5 kW/cm^2 with a single lamp. Instead of using an electrically heated resistive element to produce radiant energy, a controlled and contained plasma is used.

Since the technology is relatively new, its utility in the surface treatment of materials for applications in heavy-duty vehicles is being explored. In most cases, wear resistance, corrosion resistance, or high strength is necessary only in selected areas of the part that are exposed to the working environment or under high stress. Therefore, it would be desirable to use materials that are lighter or less expensive for the bulk of the part and have the appropriate surface properties only where required. In addition, the HDI approach would be more cost-effective than other competitive processes such as physical vapor deposition.

Results

Earlier work showed that adherent coatings of hardmetal compositions could be applied to a variety of metal substrates. Cross-sections of the coatings and base alloys revealed some large porosity within the coatings and at the interface with the underlying alloy. These bubbles are believed to be porosity that is trapped during the melting of the coating. To minimize the presence of the bubbles, the infrared (IR) treatment procedure was modified to expose the coating twice to cause the coating to remelt. The idea was that this procedure would allow the bubbles to escape during the second melting. A similar technique has been used before with silica refractories to reduce trapped porosity. The effects of double exposure on the properties of the coating and underlying base metal were mixed.

Samples of WC-(Ni-Cr-Fe) on 4140 steel are shown in Figures 1 and 2 for one-step and two-step HDI processing. No reduction in the presence of the trapped porosity was observed. However, the level of trapped porosity was decreased by allowing additional time during a one-step IR exposure, as shown in Figure 3. Evidently, the additional time during liquid formation allowed the trapped gas to escape. Some cracks in the coating were observed with the additional exposure times. In another sample, the double exposure resulted in a reduction of the trapped porosity, as shown in Figures 4 and 5. The additional exposure also appeared to increase the mixing between the coating and the underlying base metal.

As indicated, previous results had shown that adherent coatings of hardmetal compositions could be applied to a variety of metal substrates (D-2 tool steel, 4140 alloy steel, and cast iron). Selected samples with visually adherent and uniform coatings were wear-tested under dry sliding conditions using a block-on-disc tribometer. The tests were conducted with 4.5 m/s linear speed and a 60-N contact load.

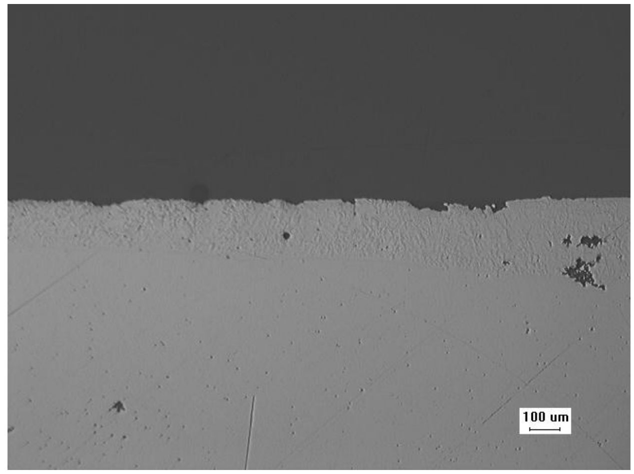

Figure 1. Cross-section of WC-(Ni-Cr-Fe) coating on 4140 steel after one-step HDI processing. IR exposure consisted of a lamp power of 900 amps for 2 sec.

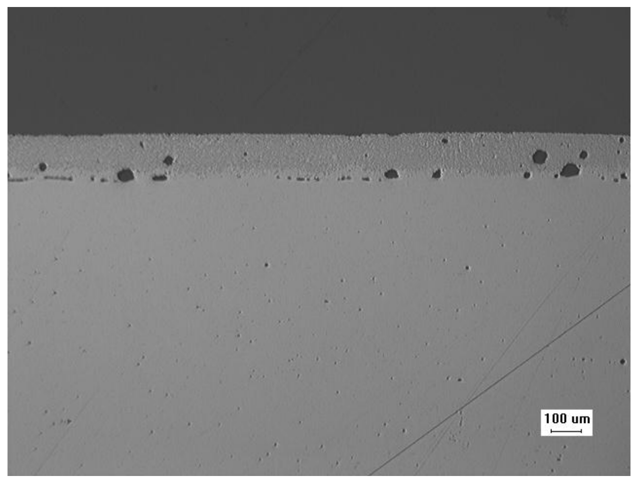

Figure 2. Cross-section of WC-(Ni-Cr-Fe) coating on 4140 steel after two-step HDI processing. IR exposure consisted of a lamp power of 900 amps for 2 sec, 15 sec non-exposure, followed by 900 amps for 1 sec.

The results are summarized in Figures 6 through 9. The wear test results on the D-2 tool steel samples showed that the HDI-coated samples exhibited significantly less wear than the as-received material. The expanded view shown in Figure 7 reveals that the WC and TiC bonded with Ni_3Al exhibited less wear than the other coated samples. A similar trend is also present in the 4140 alloy steel samples shown in Figure 8, where the TiC-Ni_3Al coating showed the best wear behavior. The cast iron samples actually showed that the WC-Ni coating performed worse than the as-received material in the wear test. How

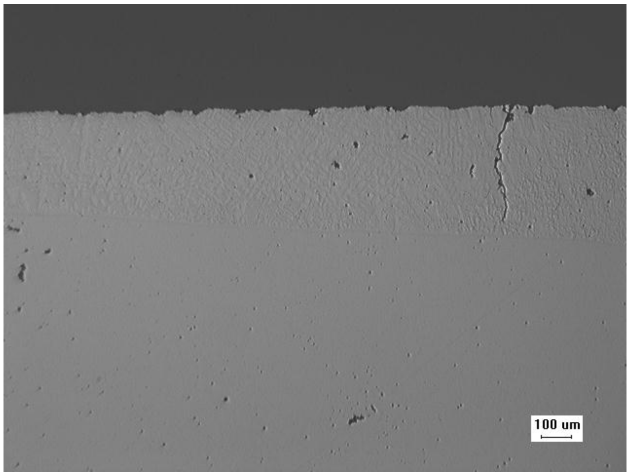

Figure 3. Cross-section of WC-(Ni-Cr-Fe) coating on 4140 steel after one-step HDI processing. IR exposure consisted of a lamp power of 900 amps for 3 sec.

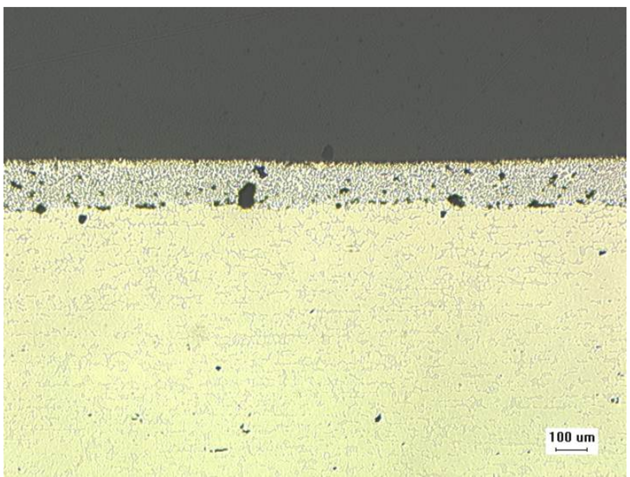

Figure 4. Cross-section of WC-Ni_3Al coating on D2 tool steel after one-step HDI processing. IR exposure consisted of a lamp power of 900 amps for 2 sec.

ever, as observed before, the Ni_3Al bonded sample exhibited the best wear behavior.

Conclusions

It was determined that adherent hardmetal-based coatings could be produced using cost-effective slurry deposition followed by boning with the HDI lamp. Hardmetal-based coatings with reduced porosity were fabricated on three different metal substrates. The wear resistance of the HDI-coated samples was significantly better than that of the as-received materials. In addition, coatings using Ni_3Al as the binder phase had superior behavior in all of the wear tests.

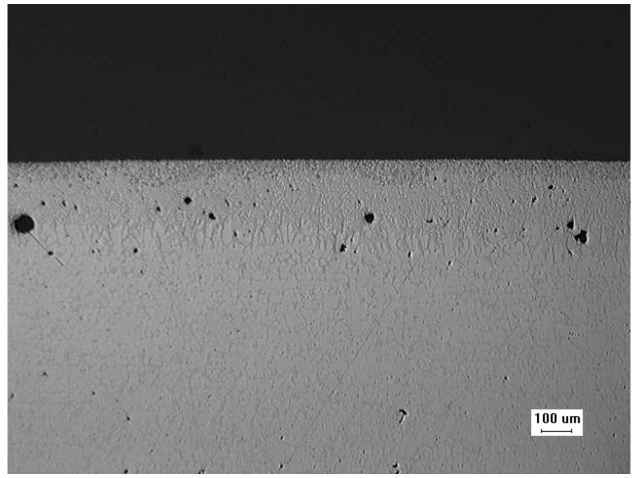

Figure 5. Cross-section of a WC-Ni_3Al coating on D2 tool steel after a two-step HDI processing exposure. IR exposure consisted of a lamp power of 900 amps for 2 sec, 15 sec non-exposure, followed by 900 amps for 1 sec.

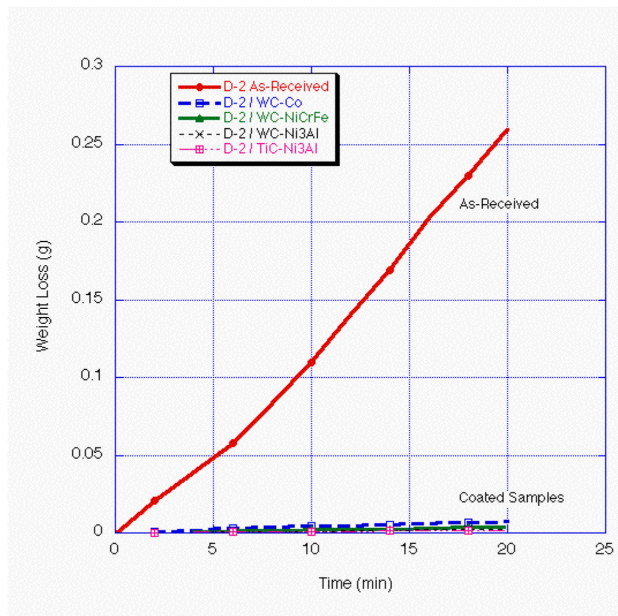

Figure 6. Wear test results on as-received and HDI-coated D-2 tool steel samples. As shown, the coated samples exhibited significantly less wear than the as-received material.

Publications/Presentations

T. N. Tiegs, "Ceramic-Metal Coatings Applied Using High Intensity Infrared Heating," presented at the American Ceramic Society Pacific Coast Conference, Seattle, WA, September 13–16, 2004.

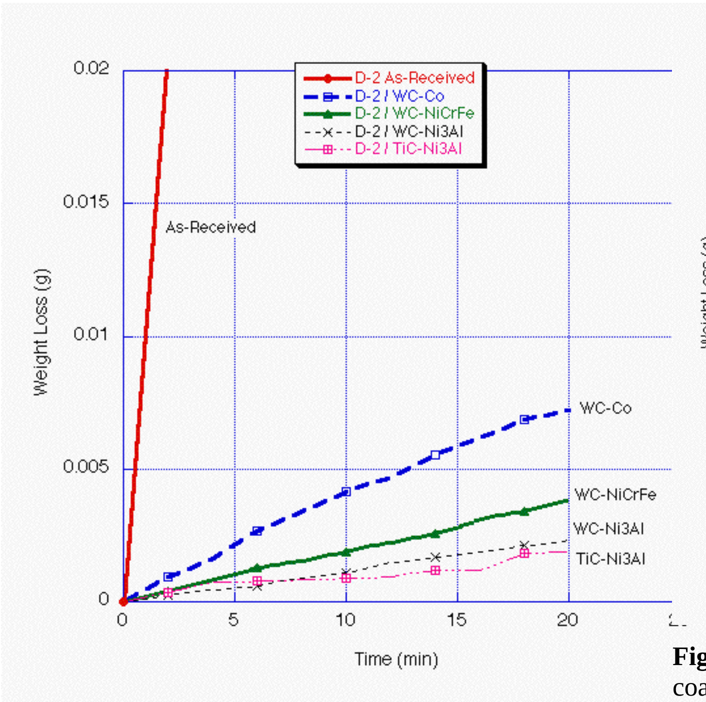

Figure 7. Wear test results on as-received and HDI-coated D-2 tool steel samples.

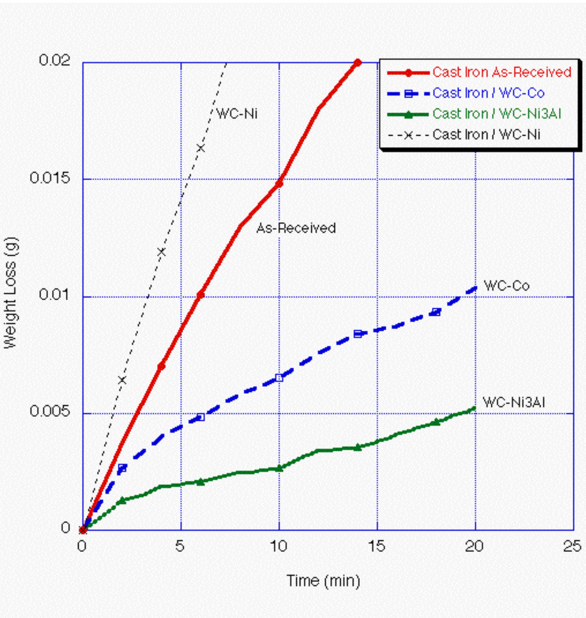

Figure 9. Wear test results on as-received and HDI-coated cast iron samples.

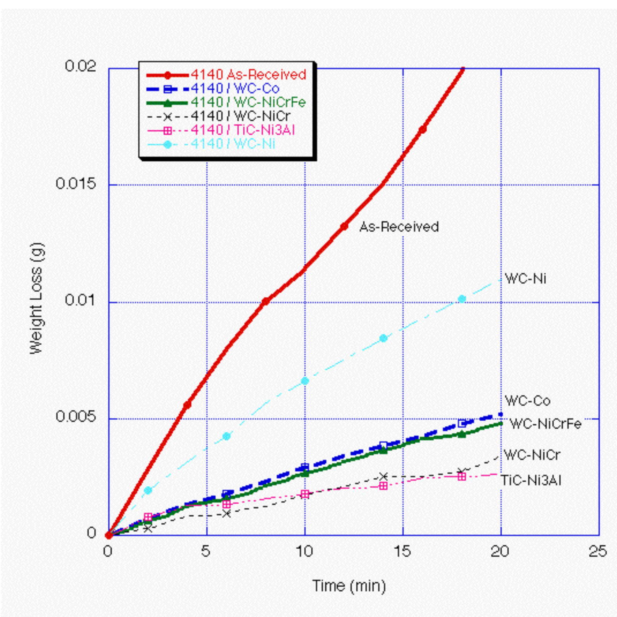

Figure 8. Wear test results on as-received and HDI-coated 4140 alloy steel samples.